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Automatic registration feasibility study: fundamental considerations

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AUTOMATIC REGISTRATION FEASIBILITY STUDY: FUNDAMENTAL CONSIDERATIONS

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AUTOMATIC REGISTRATION FEASIBILITY STUDY: FUNDAMENTAL CONSIDERATIONS

SUMMARY

This report describes some of the problems involved in the design of automatic systems of registration for three-tube and four-tube cameras. Particular attention is paid to methods of error detection and correction.

It is concluded that any fully comprehensive automatic registration system which might be added to existing cameras would require considerable additional equipment and might involve extensive modification to cameras.

Simplified forms of correction in which only some types of registration error are corrected are also discussed. These would be very much simpler and cheaper and might be sufficiently effective.

1. INTRODUCTION

Existing BBC colour television cameras use either three or four camera tubes to reproduce the scene after it has been analysed into its different spectral components. For perfect registration, the three or four images must be scanned so that corresponding points in each image are scanned by each tube at precisely the same time. If this is not achieved with sufficient accuracy, coloured fringing and possibly poor resolution will result.

Perfect registration can never be achieved in practice for the following reasons:

Scanning yokes are not identical

Camera tubes are not identical

Scanning currents are not identical

Circuits are subject to electrical drift with time and temperature

Scanning yokes and tubes suffer mechanical movement with temperature and vibration

Human errors can arise in making a large number of inter-related adjustments

Although it is very unlikely that perfect registration will ever be achieved while separate conventional camera tubes are used, there are several possible approaches to a satisfactory result.

First, a camera with sufficiently good registration and very high stability could be constructed which would maintain registration for long periods without attention.

Secondly, a limited degree of automatic compensation is feasible for a camera of somewhat lower stability to correct for drift variations which were not eliminated in the design.[1] The camera would nevertheless have to be capable of good registration in its own right, either by careful design, or by the introduction of geometry-correcting waveforms not normally adjusted after an initial setting.

Finally, an automatic correction system can be envisaged which would deal with all the registration errors associated with a camera of relatively poor performance. Such a comprehensive registration correction system would have to satisfy the following requirements:

A special chart would be needed only to apply the initial corrections.

Updating of the corrections would be achieved in the course of the camera viewing normal scenes.

A high standard of performance would be obtained even when the camera was viewing all possible types of scenes.

Negligible attention from an operator would be required.

No visible picture degradation would be introduced

The space required for equipment would be reasonably small.

Maintenance would be straightforward, and reliability excellent, so that effort saved in eliminating adjustments would not be absorbed in maintaining the correction system.

Modifications to the cameras would be an absolute minimum.

This report describes some of the principles to be observed if an attempt is to be made to meet these requirements and discusses the feasibility of comprehensive automatic correction systems for three-tube and four-tube cameras.

2. THE COMPREHENSIVE SYSTEM

The basic processes carried out in such a system are registration error detection, error information storage, and the use of the stored error information to effect correction.

The system parameters are determined by factors such as the magnitudes of the greatest and smallest errors to be corrected, the means by which error information is to be provided (charts or pictures), whether the system provides continuously updated correction or updates the correction when required, the permitted extent of modifications to existing cameras, cost and complexity.

It is envisaged that the picture would be sub-divided into a number of areas.[2] Each area would be examined for registration errors between one channel, regarded as the master, and another, regarded as the slave, which would be corrected. The error information obtained from each area would be placed in a store, either in the form of a number representing the magnitude of the error, or as a command to increase or decrease, by one, the number already in the store. The error signals contained in the store would be continuously read out in synchronism with the scanning and applied by some means to correct the registration of the slave channel.

Error detection and correction form the main subjects of this report; the storage of error information is not dealt with.

3. THE CORRECTION REQUIRED FOR THREE-TUBE CAMERAS

Previous reports[2,3] have shown the form of the differential errors that exist between pairs of scanning yokes. These basic dissimilarities of geometry between yokes give rise to misregistration which cannot be corrected by conventional camera controls, and differential errors may amount to 300 ns* at the extremities of the picture area. Mechanical and electrical drift, and human error, may account for an (estimated) additional 200 ns error. The total range of any correction device should therefore be of the order of ±500 ns. The accuracy of correction required is dictated by the fact that an error of 25 ns or more is perceptible between the green channel and the other two channels, when the latter are perfectly registered;[4] the corresponding limits for the red and blue channels are 60 ns and 120 ns respectively.

4. THE CORRECTION REQUIRED FOR FOUR-TUBE CAMERAS

Four-tube and three-tube cameras have similar scanning arrangements and therefore registration errors of similar magnitude are encountered. A permissible maximum error of 100 ns is suggested[4] between the luminance channel and perfectly registered colouring channels, and 50 ns between the green colouring channel and perfectly registered luminance, red-colouring and blue-colouring channels. The corresponding limits for the red-colouring and blue-colouring channels are 60 ns and 120 ns respectively. Satisfactory registration should therefore be achieved with a device based on an accuracy of 50 ns rather than the 25 ns required in the case of the three-tube camera. It will be seen, however, that the correction accuracy required for the red and blue-colouring channels is similar to that required in the three-tube camera. It may be argued that the registration accuracy required is such that automatic correction need not be applied to the blue channels of either three-tube or four-tube cameras however, inherent errors of greater than 120 ns exist in most cameras, at the present time, at the picture extremities.

5. ERROR DETECTION

An examination of existing scanning yokes suggests that, for a three-tube camera,[2] error information must be obtained from the areas contained in a grid theoretically not less than 7 units wide by 5 units high superposed on the picture area. This grid size should enable errors to be reduced to less than 20 ns horizontally, and the equivalent vertically, in all parts of the picture. The corresponding grid for a four-tube camera would probably need to be only 5 units wide by 4 units high since less accurate registration is required. In practice a continuous correction waveform has to be derived by interpolation between the average error in each grid square. This gives rise to some spurious information. The error detection system must therefore operate on comparatively small areas of picture information in order to evaluate the error in each grid square and it is most important that picture information should never be misinterpreted as registration errors.

Registration error information is conventionally obtained by means of a grille test chart or diascope containing regularly spaced monochrome horizontal and vertical information. Such a chart may not be convenient in many Outside Broadcast applications, and in any case the camera temporarily has to be withdrawn from production for adjustment. Automatic registration devices which require a chart therefore fulfill only a limited need since they cannot provide continuous correction for electrical and mechanical drift. If the use of a chart is, however, considered acceptable, registration error detection becomes relatively straightforward since the presence of associated edges in two channels can be guaranteed provided the signal-to-noise ratio, i.e. the contrast and lighting, are adequate. Errors may arise, however, because the signal amplitudes in the two channels being compared may not be equal, the rise times of edges in the two channels may not be equal (owing to differing bandwidths or resolution), or the noise levels in the two channels may not be equal.

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* Horizontal registration errors are expressed as the timing error in nanoseconds between any two images when scanned at the 625-line, 50 fields per second rate. Vertical registration errors are also expressed in nanoseconds assuming that the two images had been scanned vertically at the horizontal scanning velocity.

A method of overcoming these difficulties uses peak detection to determine the amplitudes of the signals together with level detection, at the half amplitude level, to reduce the effects of noise. Logical time comparison of the level detector outputs may then be made to determine the relative position of the pulses so produced.[1] This is shown in Fig. 1. The logical output may either indicate the magnitude and direction of the error, or only the direction of error, so that correction information is applied in the smallest quanta required, i.e. 20 ns each time error information is examined.

Fig. 2(*a*) shows the level detector outputs corresponding to the two channels, shown as A and B, which do not produce identical duration pulses (for some reason such as differing resolution) but do produce overlapping pulses since they are almost in register. Channel A is regarded as the master and the logical output shows Channel B as leading (early in time); if precise registration had been achieved, this being defined as symmetrical positioning of A with respect to B, the logical output would have been absent. Fig. 2(*b*) again shows the level detector outputs, but in this case a large registration error is present and the level detector outputs do not overlap. In the case of Fig. 2(*a*) the magnitude of the error can be obtained from the logical output; however, in the case of Fig. 2(*b*) the sensitivity is approximately halved and the magnitude of the error is not precisely represented by the duration of the logical output.

The main advantage of this approach is its simplicity. The main disadvantage is that there is no limit to the magnitude of the error measured unless special precautions are taken; this is necessary since, if pulse B in Fig. 2 were for any reason absent, a large registration error would be indicated. This situation should not normally occur with a test chart, but could do so if the small areas being examined were not reasonably accurately related to the pattern of the test chart. This requires accurate camera alignment on the test chart.

This method is directly applicable to horizontal error detection. Vertical error detection would be very similar except that narrow sample pulses would be used to provide a vertical section of the picture information. These samples could then be interpolated to provide a continuous waveform which could be examined as before. The effective bandwidth of the vertical signals is fundamentally restricted since information from only one field is available at any one time. This is equivalent to a minimum rise time of 136 equivalent vertical nanoseconds in the interpolated output. This is, however, of the same order as the resolution of the Plumbicon tube.

The resolution of the Plumbicon tube itself is a limiting factor and to obtain consistent indications of less than 20 ns error from signals with rise times of the order of 130 ns both horizontally and vertically is not likely to be readily achieved, although errors of this magnitude would be just visible to the human eye.

In the case of the four-tube camera, the colouring channel signals are normally limited to a bandwidth of 1·5 MHz in the head amplifiers and filters in the camera head; thus signals with rise times of not less than 330 ns are available for horizontal error detection at the control unit. The required detection accuracy in this case is better than 50 ns. This will be even more difficult to achieve than in the three-tube camera since the rise times of the signal information are even greater in relation to the detection accuracy required.

In order to provide registration error information from picture information, a completely different approach is required, since edges in any two channels need not necessarily correlate in magnitude, direction or rise time. Only in the case of monochrome scenes can correlation of these edges be assumed. In coloured scenes very little correlation may exist, even at colour transitions, and in many cases positive going edges in one channel will correspond to negative going edges in another channel.

In order to provide the required information from the examination of small areas of the picture, it is thought that the following basic principles should be observed:

> Only large amplitude edges in the picture should be used, in order to provide protection against

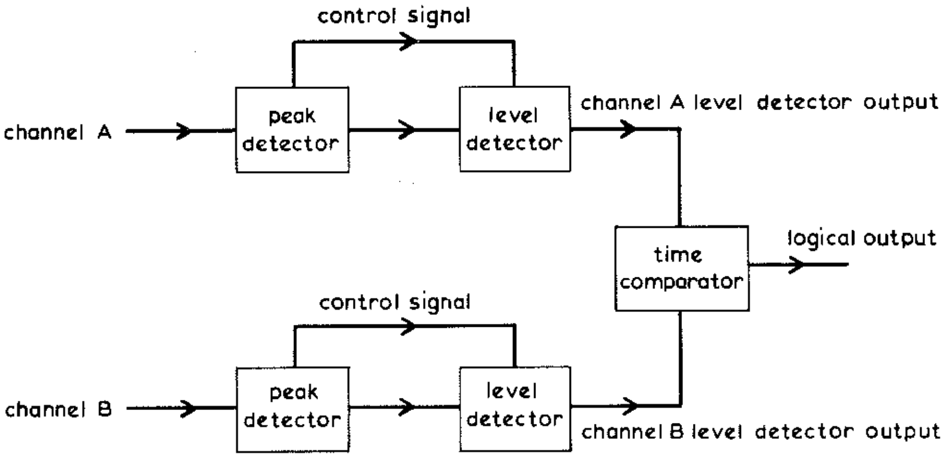

Fig. 1 - Block diagram of logical error detector

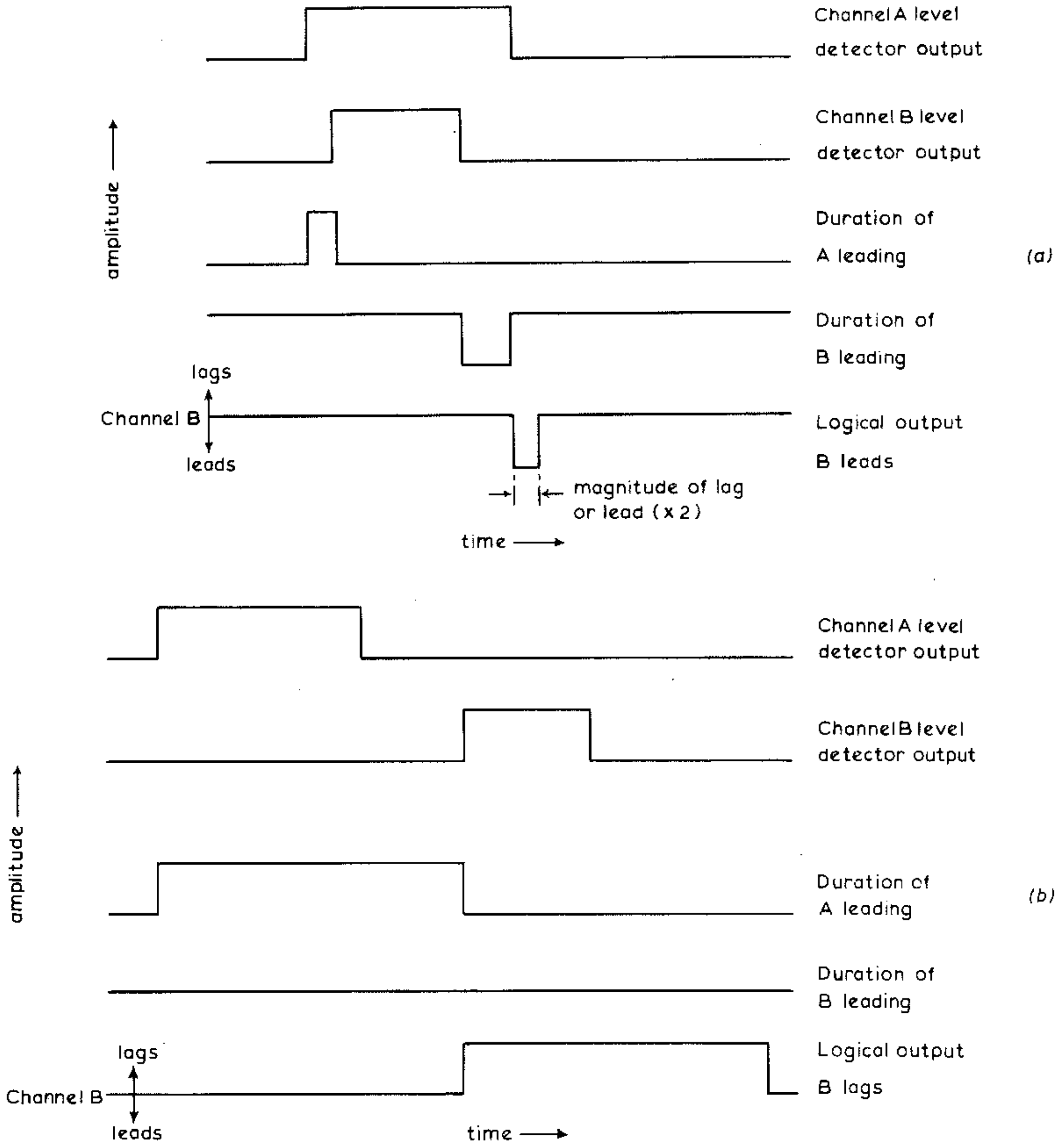

Fig. 2 - Logical error measurement
(*a*) Small registration error (*b*) Large registration error

noise and also to increase somewhat the probability that a corresponding edge exists in another channel.

The edges should have a sufficiently short rise time before being interpreted as picture detail, so that registration error information can be extracted with the greatest possible precision.

Edges from the channels compared should occur within a small interval if colour detail is not to cause false error information. The implication of this is that an error detector with a range of ±500 ns would be unsatisfactory and a limit of approximately ±50 ns would be necessary; even then some spurious error indications would be given. As a result, initial registration would almost certainly have to be carried out on a test chart with the error detector arranged to operate over a wide range, while continuous small corrections are subsequently provided on picture detail with the error detector ignoring all information relating to misregistration of greater than ±50 ns.

Integration of errors over the area of each grid square should be provided to guard against the effects of noise. The larger each grid square can be permitted to be, the more effective the integration can become.

A possible form of error detector would be that described in a proposal[5] in which derivatives of the picture information from two channels are used to provide information which may be compared. In a horizontal error detector this process involves the use of short-circuited delay lines with a delay of the order of 150 ns to provide derivatives and ramp waveforms for time measurement. More recently a simpler type of detector has been developed[6] which is suitable for examining large areas of picture for registration errors and may therefore be used with simpler types of registration correction system.

A vertical error detector using derivatives and ramp waveforms would require low bandwidth one line period delays, to carry out the analogous operations. This is feasible but physically bulky. A vertical error detector analogous to the simplified horizontal detector has recently been devised[7] and is also suitable for simplified registration correction systems.

6. THE APPLICATION OF ERROR INFORMATION TO EFFECT CORRECTION

The error information from the store would be available as two independent correction waveforms to be applied to each 'slave' channel. One represents the vertical error information and is a complex waveform with a frequency spectrum extending from d.c. to approximately 100 kHz. The other waveform represents horizontal errors and contains signals of similar bandwidth. These signals must be applied to the camera so that there is a reasonably linear correction of the effective position of the scanning spot, free from overshoots.

Two approaches are possible for applying these corrections.

6.1. Correction by Means of Delay Lines

Horizontal errors can be corrected by the use of delay lines with a delay variable between approximately zero and 1 μs. These could be placed in the red and blue signal paths of a three-tube camera with a fixed delay of 0·5 μs in the green channel. Ideally the delays should be continuously variable but in practice they would probably have to be changed in discrete steps of the order of 20 ns; provided the steps are a small fraction of a picture element no loss of resolution should occur.

Fig. 3(*a*) shows a simplified block diagram of the signal paths in a typical three-tube camera.

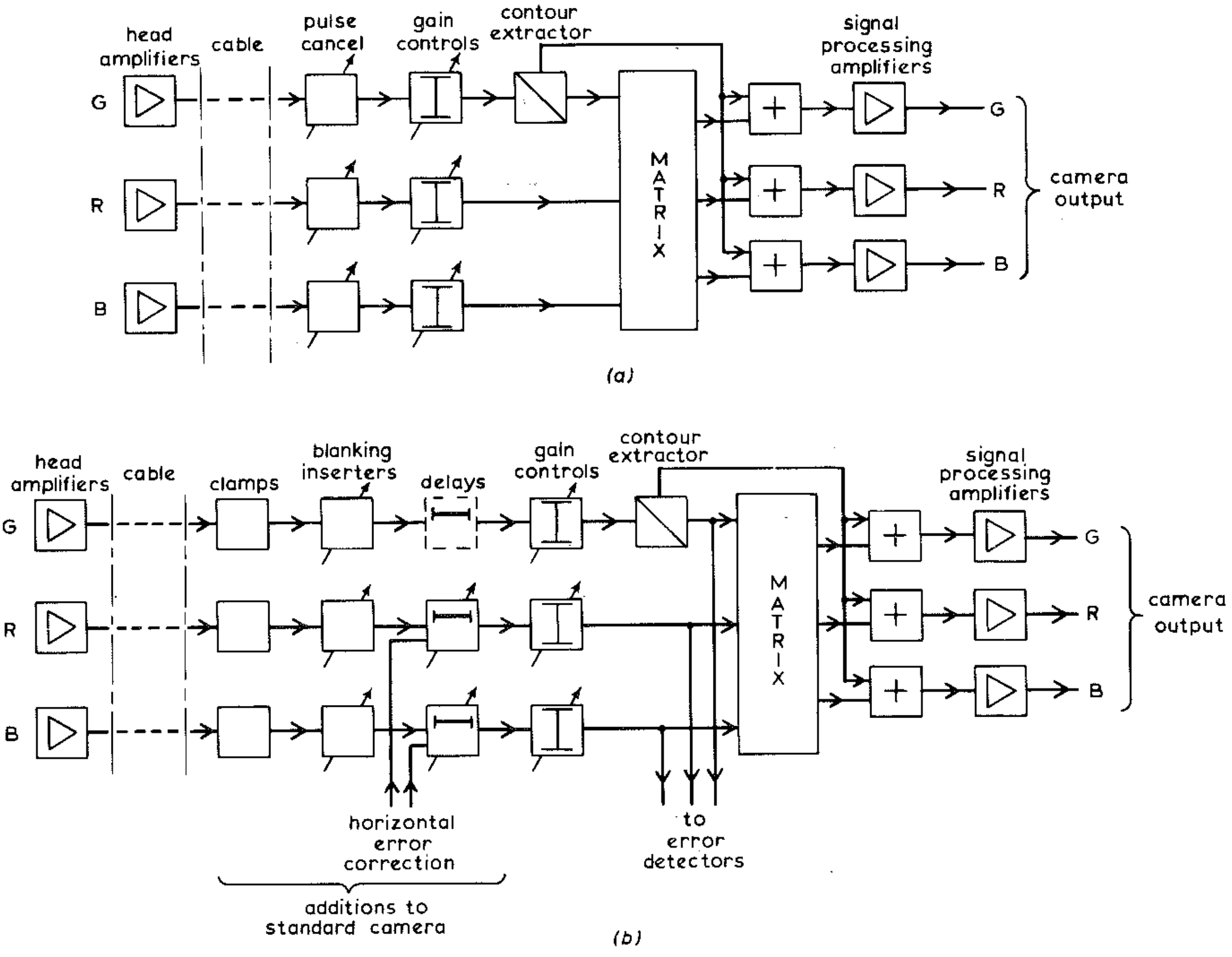

Fig. 3 - Block diagrams of typical three-tube camera signal processing
(*a*) Standard camera signal processing (*b*) Signal processing modified for automatic registration

The video signals from the camera tubes are amplified and passed down the camera cable unprocessed, the head amplifier gains being pre-set. Pulse cancellation consists of adding a line frequency pulse, adjustable in amplitude and polarity, during the camera blanking interval so that the subsequent clamping operation in the signal processing circuitry occurs at a level corresponding with signal black level. The gain controls adjust the signal levels at the input to the matrix to be equal when a grey scale is reproduced by the camera. Information in the form of vertical and horizontal contour correction signals is extracted from the green signal and fed equally to all channels.[8,9]

The signals are subsequently blanked, gamma corrected etc., in the normal way.

Fig. 3(*b*) shows the additions and alterations necessary to implement horizontal registration correction by means of adjustable video delay. The first operation that must be performed on the signals in the Camera Control Unit is that of clamping to establish the d.c. component. This is followed by gating, using a line-blanking waveform of shorter duration than system blanking; the blanking level must be variable and used as the pulse-cancelling adjustment. Gated blanking is essential to maintain the black level after subsequent clamping operations, since the video delay changes with registration correction and because interpolated correction signals extend into the blanking period and would otherwise cause unwanted variations of the timing of inter-line spurious signals. The adjustable delay correctors are then inserted. A fixed 0·5 μs delay in the green channel probably need not be provided since d.c. shift can be applied to the scanning to ensure registration at the centre when the adjustable delays are set to mid-range.

The signals for error detection are extracted immediately before the matrix unit, and beyond this point the signals are treated as if they were pulse-cancelled waveforms from the camera. Spurious signals and switching transients arising in the variable delay lines may pose problems because subsequent gamma correction will increase their visibility near black.

Correction of vertical registration errors would require seven television lines of delay for the equivalent ±500 ns correction and interpolation between each of the seven lines would be required in order to provide shift in the vertical direction corresponding to a fraction of a line spacing. The degradation of the picture quality after passing through large delays would probably be severe. The adjustable vertical delay system could be placed either immediately before or after the adjustable horizontal delays in Fig. 3(*b*).

Very similar considerations apply in the case of the four-tube camera. Fig. 4 shows a simplified block diagram of a typical four-tube camera with the variable delays placed in the three colouring channels. The luminance channel is regarded as the master. The signals at the points at which the delays are inserted are already pulse cancelled with narrow blanking inserted by gating at picture black level. Additional processing of the signals is therefore not required and the operation of the variable delays should cause no trouble in the subsequent signal processing circuits. As with the three-tube camera, a 0·5 μs line-drive advance may be required to ensure that the effects of line scan flyback are not visible in the picture after system blanking has been added. The discrete steps of the delay lines can be increased in duration to 40 ns in the case of the

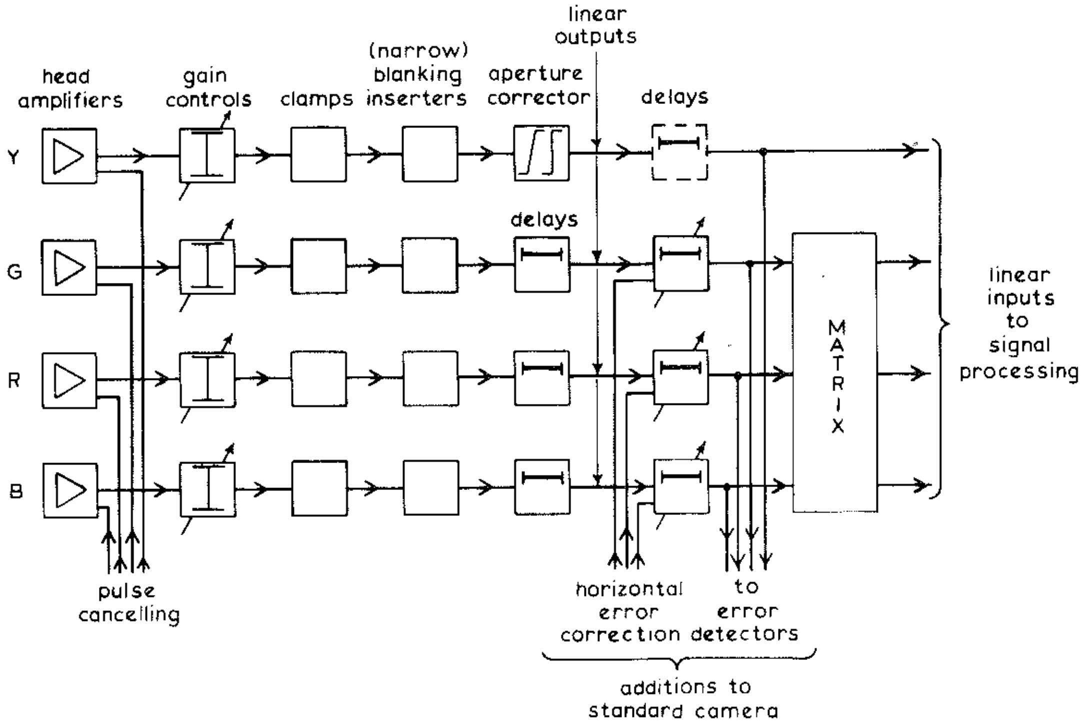

Fig. 4 - Block diagram of typical four-tube camera signal processing

green channel, 60 ns in the red channel and 120 ns in the blue channel. The spurious signals caused by the operation of the delay line would probably not be visible because the four-tube configuration is fairly tolerant of noise in the colouring channels. If, however, changes of delay in comparatively coarse steps were adopted for simplicity, then the level of spurious signals might also be increased.

Vertical registration errors could probably be corrected by means of delay lines, since the resulting degradation of vertical resolution should be acceptable in colouring channels.

6.2. Correction by Means of Scan Perturbation

The correction of horizontal errors by the addition of current waveforms corresponding to the errors has not been studied in detail, as it was originally considered preferable to use the adjustable delay technique. Since line scan generation is usually carried out in the camera-head, changes in the camera cable utilisation would be necessary to send two (in the case of a three-tube camera) or three (in the case of a four-tube camera) additional wide-band (100 kHz) signals from the control unit to the camera-head to correct the slave channels.

The correction of vertical errors is somewhat easier since field scan generators are typically in the control unit. The required correction currents may therefore be added to the field scan current at the control unit and no modification to the camera head or camera cable utilization is then necessary. Several problems do, however, arise if this technique is used. A detailed discussion will be found elsewhere[10] but the main points will be briefly summarized.

The scan coils are inductive (typically 20 mH) and therefore present a relatively high impedance at the maximum correction frequency; this impedance rising with frequency must be compensated in order to drive the scan coils with constant current. Compensation for camera cable length must also be provided since the conductors used for carrying the field scan currents have an appreciable loss at 100 kHz.

It is also necessary to supply additional current to the field scan coils at high frequencies to compensate for losses due to capacitive coupling between the field scan coils and the other coils in the deflection yoke.

7. CONCLUSIONS

This report is a 'feasibility study' of the possibility of introducing comprehensive automatic registration correction as an addition to existing colour cameras. Any comprehensive system will require considerable equipment and, in some forms might involve extensive modification to existing cameras. The cost and bulk of such equipment may well be too great. An alternative cheaper solution, but offering less complete correction might be preferable.

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